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ABSTRACT

The purpose of this study was to review the research on sex-related differences in mathematics achievement to determine the extent of the inequalities and the factors which cause them. The first section concentrates on differences in mathematics achievement between males and females. The second section describes the sex differences in mathematics course enrollment and the factors identified by males and females which predict course enrollment. The third section discusses student attitudes, teacher-student interactions, and parent attitudes. The annotations within each category are arranged chronologically. Recommendations include: (1) Teachers at all levels should eliminate sex bias; (2) Educators and parents should encourage all students to continue in mathematics; (3) Research be should conducted on sex differences of math-related activities which occur outside school and their relationship to math achievement; (4) Educators and parents should help students develop confidence in their ability to do mathematics; (5) Educators should demonstrate to students the usefulness of math in their lives; (6) Research should be conducted on learning when the frequency of certain mathematics activities is manipulated; (7) Research should be directed toward the teaching of spatial visualization; (8) Teachers should help students overcome sex stereotyping of mathematics; and (9) Teachers and parents should cooperate to increase supportive conditions and encourage perseverance. (PK)

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Sex Differences in Mathematics Achievement: What Are They and Why Do They Exist?

by

Denise L. Gerig

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INTRODUCTION

In recent years, computers and advanced technology have become an integral part of every aspect of society. For this reason, the study of mathematics has become an essential component for many careers. "Students, parents and even school personnel often do not realize that advanced mathematics is necessary for a university degree even in such a traditionally female area as nursing, not to mention its increasing importance in the social sciences, and the mathematics emphasis in examinations for admission to professional schools" (Fennema and Sherman: 1977). Even with this knowledge, "mathematics is a subject in which males continue to outperform females" (Peterson and Fennema: 1985). Without particular attention to equity issues, the technological revolution could increase the advantage males have over females in these areas.

One aspect of inequities in mathematics achievement concerns enrollment in advanced mathematics courses. "Females are much less likely than males to take certain higher level mathematics and quantitative science courses" (Pallas and Alexander: 1983). "Because of the impact of mathematics on career development, study of the factors relating to girls' and boys' continuation in courses of theoretical mathematics is of considerable practical importance" (Sherman: 1981). These factors can have a serious effect on students' math achievement.

In recognizing the sex-related differences in mathematics achievement, researchers have identified specific student

attitudes which may affect course enrollment. "These negative attitudes undoubtedly contribute(d) to the increasing differential in the enrollment of the two sexes in advanced mathematics classes" (Fennema and Sherman: 1978).

Educators have been accused of encouraging sex-stereotyped roles in mathematics classrooms. "The differences found generally work in a positive way for males - they receive(d) more teacher attention, reinforcement, and affect. Females, traditionally the 'lesser sex', receive(d) less of all three" (Becker: 1981).

The final aspect which has been suggested to perpetrate sex differences in math achievement is parental attitudes. "A child's self-assessment of and attitudes toward math may be more strongly related to their parents' perceptions of their abilities and attitudes than the child's own past performance" (Jayaratne: 1983).

All of these aspects of mathematics equity are important to the educational achievement of females. The educational advantages and potential economic benefits to be gained from increasing mathematics achievement make the question of equity a matter of extreme importance for educators.

STATEMENT OF THE PROBLEM

Inequities between males and females in mathematics achievement and mathematics course enrollment have been revealed in many studies (Peterson and Fennema: 1985). It has become clear that unless these inequities are dealt with, females will continue to fall behind in this world of increasing technology. If this is to be prevented, an examination of the inequities and the factors which cause them must be studied carefully. Methods must be found to encourage and involve all students in mathematics.

PURPOSE OF THE STUDY

The purpose of this study was to review the research on sex-related differences in mathematics achievement to determine the extent of the inequalities and the factors which cause them. It was hoped that an awareness of the problem would encourage educators to form strategies that would help to eliminate the inequities and increase the opportunities for all students.

ORGANIZATION OF THE STUDY

The first section of this study concentrates on the basic differences in mathematics achievement which have been found between males and females. The second section describes the sex differences in mathematics course enrollment and the factors identified by males and females which predict course enrollment.

The third section discusses in detail the three major sociological factors which were identified in section two. These factors are student attitudes, teacher-student interactions, and parent attitudes.

The annotations within each category are arranged chronologically.

LIMITATIONS OF THE STUDY

The study of sex differences in mathematics achievement resulted in an abundance of materials. Many articles presented opinions as to why these sex differences occurred. This study concentrated on research articles, therefore the above mentioned articles were not included. Many articles discussed differences in math achievement that exist for groups according to race and socioeconomic status. Only the sections dealing with male-female differences were discussed here.

One final limitation was the exclusion of intervention programs which have been developed to combat the inequities.

Most of these programs were developed recently and did not contain a great deal of statistical data as to their effectiveness; therefore they were not included.

DEFINITIONS OF TERMS

ability - "the actual power present in an organism to carry to completion any given act or to make adjustments successfully, the response being subject to voluntary control and dependent on the motivation of the subject to do his best performance" (Good: 1973).

achievement - "accomplishment or proficiency of performance in a given skill or body of knowledge" (Good: 1973).

arithmetic reasoning - "the ability to solve by reasoning a verbal problem in arithmetic" (Good: 1973).

Attribution Theory - "personal explanations of causality (attributions) fall into one of four categories: ability, effort, task difficulty, or luck. These four categories are derived from two factors, each of which has two levels - locus of causation (internal/external) and degree of stability (stable/unstable)" (Wolleat et. al.: 1980).

Brophy-Good Teacher-Child Dyadic Interaction System - "records only interactions involving the teacher and an individual student. The instrument records who initiates a contact and whether it is public or private, academic or nonacademic" (Becker: 1981).

competitive activities - "conscious struggle or rivalry in which one person or group seeks the same object that is sought for by others at the same time; a contention of two or more persons or groups, short of open conflict, for the same object or goal" (Good: 1973).

computation - "that phase of mathematics which emphasizes the operational skills only" (Good: 1973).

cooperative activities - "group experience, physical, intellectual, or emotional, designed to achieve a common purpose" (Good: 1973).

Fennema-Sherman Mathematics Attitudes Scales - "consist of eight 5-point Likert scales measuring attitudes toward mathematics (range 12-60 for each). Split-half reliabilities range from .87-.93. Each scale consists of twelve items, half weighted negatively and half positively. The scales are Confidence in Learning Mathematics; Mother, Father, and Teacher Scales (perceived attitudes of each of these persons toward one as a learner of mathematics); Usefulness of Mathematics; Effectance Motivation in Math (joy in problem solving); Attitude toward Success in Mathematics; and Math as a Male Domain" (Sherman: 1982).

learning environment - "This aspect of the classroom includes formal and informal rewards and punishments, beliefs and values communicated to the students, and the physical environment itself" (Becker: 1981).

math applications - "school mathematics in which the topics are selected for and the teaching aimed at some particular use of mathematics" (Good: 1973).

Math as a Male Domain Scale - "concerns opinions that females cannot do math as well as males or that females who do well in math are peculiar or masculine. Scores for this scale range from low score, math seen as a male domain, to high score, math seen as sex-neutral" (Sherman: 1982).

math concepts - "in reference to content, a term used by different writers to mean anything in or related to mathematics which is not considered a skill" (Good: 1973).

Mathematics Attribution Scale - "designed to measure high school students' perceptions of the causes of their performance in the content-specific area of high school mathematics" (Wolleat et. al.: 1980).

mathematics skill - "ability to use the operational techniques of mathematics" (Good: 1973).

Mechanical reasoning - "ability to understand physical principles as applied to mechanical devices" (deWolf: 1981).

proofs - "an argument employing valid reasoning which shows some general mathematical assertion to be necessary consequence of accepted premises which may be formalized as axioms, theorems, etc" (Good: 1973).

quantitive ability - ability which can be measured directly (deWolf: 1981).

Scholastic Aptitude Test - "composed of two parts: the mathematics (SAT-M) and the verbal (SAT-V) tests. The mathematical section is particularly designed to measure mathematical reasoning ability" (Benbow and Stanley: 1980).

spatial visualization - "the ability to mentally manipulate, rotate, twist, or invert a pictorially presented stimulus object" (Fennema and Tartre: 1983).

teacher expectancy - a term descriptive of a predicted level of success, such as an expectancy level of performance in mathematics as predicted from teacher's perception of the student (Good: 1973).

teacher wait-time - "the length of time a teacher waits for a student to begin responding to a teacher-posed question" (Gore and Roumagoux: 1983).

verbal skills - "the ability to respond adequately in a situation requiring the communication of thought" (Good: 1973).

Annotations

DIFFERENCES IN MATHEMATICS ACHIEVEMENT

Benbow, C. P., and Stanley, J. C. Sex Differences in Mathematical Ability: Fact or Artifact?. Science, 12 December 1980, 210(4475), 1262-1264.

Benbow and Stanley used the data collected by the Study of Mathematically Precocious Youth (SMPY) of 9927 gifted junior high school students from the years 1972-1979. The students in the SMPY took the Scholastic Aptitude Test (SAT). An analysis of the data found a large sex difference in mathematical ability in favor of boys in all 6 talent searches. The greatest disparity was in the upper ranges of mathematical reasoning ability. Boys outnumbered girls 2 to 1 in SAT-M scores over 500. This difference of scores was observed before girls and boys started to differ in the numbers and types of math courses taken. It was noted that more boys than girls (57% to 43%) entered the talent search each year.

Fennema, E., and Carpenter, T. P. Sex-Related Differences in Mathematics: Results from National Assessment. Mathematics Teacher, 1981, 74(7), 554-559.

This article reported on the sex-related differences that were found in the National Assessment of Educational Progress. The data indicated that there was very little difference between females and males in the math courses taken in the early portion of the high school math sequence. No clear pattern of differences in achievement was apparent at the ages of 9 or 13. By the age of 17 however, male performance exceeded female performance at every cognitive level. Achievement differences still existed when course background was taken into account. Females tended to score higher on lower level number and numeration skills at ages 9 and 13. Males scored higher on multi-step word problems at all age groups. For 9 and 13 year olds, there was a consistent pattern of lower averages for females on geometry and measurement exercises over all cognitive levels tested.

Senk, S., and Usiskin, Z. Geometry Proof Writing: A New View of Sex Differences in Mathematics Ability. American Journal of Education, 1983, 91(2), 187-201.

The data reported in this article were from the Cognitive Development and Achievement in Secondary School Geometry project. The study was conducted during the 1980-1981 school year. Only those students who took a proof test and the entering geometry test(EG) were reported on in this study. More males than females were in the higher track geometry classes. The mean scores for girls were significantly lower than the mean scores for the boys on the proof test. However, when the proof scores were adjusted for differing EG scores, females scored higher than the males on all forms of the proof test. These results seemed to indicate that although girls entered geometry with less knowledge, by the end of the year there was no significant difference in proof-writing performance between the girls and boys.

Fennema, E., and Tartre, L. A. The Use of Spatial Visualization in Mathematics by Girls and Boys. Journal for Research in Mathematics Education, 1985, 16(3), 184-206.

This study was designed to give information about how spatial visualization and verbal skills are used in problem solving and whether this usage differed by sex. Results showed that the boys solved more problems correctly than the girls. There was a difference in the ability to solve mathematical problems in favor of the boys. After 3 years of study, Fennema and Tartre found that although students who were discrepant in spatial visualization and verbal skills differed in the processes they used to solve problems, they did not differ in their ability to solve the problems. A problem-solving process that emphasized the use of spatial visualization skills helped to solve more problems than any other process. Boys who were low in spatial visualization and high in verbal skill had the highest achievement scores in grades 6 and 8. The scores of girls low in spatial visualization dropped in relation to the total sample. All the differences found were small and the intrasex differences were larger than the intersex differences.

Hanna, G. Sex Differences in the Mathematics Achievement of Eighth Graders in Ontario. Journal for Research in Mathematics Education, 1986, 17(3), 231-237.

Data for this report were collected by the Second International Mathematics Study of the Internatonal Association for the Evaluation of Educational Achievement. There were no statistically significant differences found between the boys and girls for arithmetic, algebra and probability and statistics. More boys gave correct responses on the geometry and measurement tests. Both sexes gave incorrect responses with similar frequency. The percent of omitted responses was greater for the girls than for the boys. An examination of the gains made from the pre-test to the post-test indicated that instruction had about the same influence on the girls as on the boys.

Moore, E. G., and Smith, A. W. Sex and Ethnic Group Differences in Mathematics Achievement: Results from the National Longitudinal Study. Journal for Research in Mathematics Education, 1987, 18(1), 25-36.

This study used data obtained from the National Longitudinal Study of Labor Force Behavior. The sample consisted of 11,914 men and women, ages 15 to 22. The individuals came from all segments of society and were sampled by direct home visits. A strong pattern of increased test scores with increased education was seen for all groups. Male respondents generally outperformed their female counterparts. For those subjects who reported completing grades K-8, females scored slightly higher on mathematics knowledge, but there was no significant difference between males and females on arithmetic reasoning. Those completing grades 9-11 showed no significant difference on mathematics knowledge, but a difference in favor of the males showed up on arithmetic reasoning. The final category, consisting of those who had completed high school or had some college experience, showed a significant advantage for males over females on mathematical knowledge and arithmetic reasoning.

Brandon, P. R., Newton, B. J., and Hammond, O. W. Children's Mathematics Achievement in Hawaii: Sex Differences Favoring Girls. American Educational Research Journal, 1987, 24(3), 437-461.

This paper reported on data collected for grades 4, 6, 8, and 10 on the Stanford Achievement Test. The data was collected during the 1982-83 and 1983-84 school years. Hawaii's four major ethnic groups (Caucasians, Filipinos, Hawaiians, and Japanese) were examined. Girls outperformed boys on 76 of the 80 comparisons made between the sexes. The only areas where boys outscored girls was in the 4th grade test on math concepts and on the 6th grade test on mathematics applications. These differences occurred both years of the study. It was also found that Hawaii public school girls outperformed public school boys even in the subtests' highest percentiles.

DIFFERENTIAL COURSE ENROLLMENT

Sex Differences in Enrollment

deWolf, V. A. High School Mathematics Preparation and Sex Differences in Quantitative Abilities. Psychology of Women Quarterly, 1981, 5(4), 555-567.

The Washington Pre-College Test Battery (WPC) and transcripts of 2093 high school juniors were analyzed in this report. Results indicated that men took more math courses and scored higher on tests of quantitative ability while women earned higher grades. When the amount of coursework was controlled, the sexes did not differ in their degree of predictability on the subtests, Quantitative Skills and Math Achievement. WPC Spatial Ability was also uninfluenced by sex once prior math training was controlled. Two areas, Applied Mathematics and Mechanical Reasoning, were influenced by sex regardless of the control exercised over coursework preparation.

Armstrong, J. M. Achievement and Participation of Women in Mathematics: Results of Two National Surveys. Journal for Research in Mathematics Education, 1981, 12(5), 356-372.

Jane Armstrong analyzed 2 sources of data for this report. The first source of data came from the Women in Mathematics Project (WMP). The second source of data came from the second mathematics assessment conducted during 1977-78 by the National Assessment of Educational Progress (NAEP). The WMP found that males in the 12th grade were favored on all 4 subtests, while 13 year-old females outperformed males on the computation subtest and were equal on everything else. The NAEP found no sex differences for computation or algebra for the 17 year-olds, but there was a large difference favoring males on an application exercise. A look at the 13 year-olds results found that females did significantly better on computation than males, but males outscored females on problem-solving skills. Significant sex differences in enrollments were found in both studies. These were most pronounced for the higher level mathematics courses of trigonometry and precalculus/calculus with more boys than girls enrolling in them. A difference in spatial visualization was found only at the lowest level of participation, where males did score higher than females.

Sherman, J. Factors Predicting Girls' and Boys' Enrollment in College Preparatory Mathematics. Psychology of Women Quarterly, 1983, 7(3), 272-281.

Sherman briefly reviewed research examining the differences between males and females in mathematics. Her study tested students in the eighth grade and again in the eleventh grade to see what mathematics courses they had elected to take. Her results suggested that males performed lower than females, but expressed more confidence in their mathematics performance. She recommended that females need to develop spatial visualization skills and the perceived usefulness of math.

Pallas, A. M., and Alexander, K. L. Sex Differences in Quantitative SAT Performance: New Evidence on the Differential Coursework Hypothesis. American Educational Research Journal, 1983, 20(2), 165-182.

The testing data for this study came from the School and College Ability Test and the SAT. Student questionnaires were used to obtain data on the educational attainment of father and mother and the student's sex. An examination of results found no significant sex differences in father's education, mother's education, race, or 9th grade quantitative test performance. Females were much less likely to take certain higher level math and quantitative science courses. They did receive somewhat higher GPA's in the courses they did take. Females still scored somewhat lower on SAT-M even after adjusting for sex differences in quantitative coursework. However, this adjusted deficit was far less than the original difference.

Rallis, S. F., and Ahern, S. A. Math and Science Education in High Schools: A Question of Sex Equity?. Educational Resources Information Center, ED 270 326, American Educational Research Association, San Francisco, California, April 1986, 32p.

This study focused on the mathematics and science course enrollment of the 1985 class of seniors in Rhode Island. Files of every senior in the sample were used to collect data on all the mathematics and science courses taken and the grades received in these. More males were enrolled in general mathematics and pre-algebra. Female enrollment was greater for the pre-college sequence. Advanced Mathematics drew a total of 114 females to 100 males. Females tended to receive higher grades for their work. Females were awarded 60% of all A's and 52% of all B's. Males, on the other hand, received 54% of all C's. One disturbing finding was that only 20% of all seniors in the sample took 8 or more mathematics and science courses.

Predictors of Mathematics Enrollment

Sherman, J., and Fennema, E. The Study of Mathematics By High School Girls and Boys: Related Variables. American Educational Research Journal, 1977, 14(2), 159-168.

This study wanted to determine the relationships between important affective, cognitive, and other variables and the decision to enroll in further mathematics classes. Tenth and eleventh graders were asked whether or not they were planning to take math in the next year. The students were then divided into high math achievement and low math achievement groups. In the 10th grade, more lower and upper level boys than girls intended to continue to study math the next year. In the 11th grade, there was no difference between the girls and boys in the upper level of achievement. In the lower level, more boys than girls intended to continue in math. After taking out the effect of verbal ability, spatial visualizaton and math achievement, all affective variables except Math as a Male Domain differentiated between groups. Boys tended to stereotype math as more of a male domain and girls showed more effectance motivation.

Sherman, J. Girls' and Boys' Enrollments in Theoretical Math Courses: A Longitudinal Study. Psychology of Women Quarterly, 1981, 5(5), 681-689.

Sherman followed students from the first year to the fourth year of high school to determine the factors that were related to continuing enrollment in theoretical mathematics courses. Subjects were grouped according to 1, 2, 3, or 4 years of math. Affective variables were measured by the Fennema-Sherman Mathematics Attitudes Scales. Students who continued in mathematics had more favorable scores on nearly all variables except Attitude toward Success and Math as a Male Domain. The top 4 factors which affected continuation in mathematics for females were: (1) Spatial visualization, (2) Quick Word Test, (3) Usefulness of Mathematics, and (4) Confidence in Learning Mathematics. The top 4 factors for males were: (1) Confidence in Learning Math, (2) math achievement, (3) Math as a Male Domain (stereotyped more as a male domain), and (4) Effectance Motivation in mathematics.

Benbow, C. P., and Stanley, J. C. Consequences in High School and College of Sex Differences in Mathematical Reasoning Ability: A Longitudinal Perspective. American Educational Research Journal, 1982, 19(4), 598-622.

This investigation was a continuation of the Study of Mathematically Precocious Youth (SMPY) done between 1972-1974. At the time of the original talent search, boys in each wave scored significantly higher on the SAT-M than the girls. Girls scored higher on the SAT-V. After taking the SAT in high school, the males' scores improved more than the females' scores did on both the SAT-M and the SAT-V. SMPY boys and girls reported that they liked mathematics equally. Attitudes toward math measured at the time of the talent search and in high school could not predict the number of semesters of math taken. There were some indications that girls participated in math less than boys not because they liked it less, but because they liked verbal areas more than boys did.

Sherman, J. Continuing in Mathematics: A Longitudinal Study of the Attitudes of High School Girls. Psychology of Women Quarterly, 1982, 7(2), 132-140.

This study dealt with two questions: (1) Are attitudes toward math behavior a causal factor affecting girls' enrollment in math classes? (2) What changes occur in girls' attitudes toward math over the high school years? Girls were divided into 3 groups depending on how many years of mathematics they had taken. Group 4 girls were enrolled in the 4th year of college preparation mathematics, group 3 girls had 3 years of math, and group 2 girls had 1 or 2 years. Groups were equated on the basis of 9th grade scores on vocabulary and spatial visualization. The Fennema-Sherman Mathematics Attitudes Scales were given before the enrollment behavior occurred. Overall significant differences were found for Usefulness of Math, Confidence in Learning Math, Teacher Scale and Effectance Motivation in Math. Group 4 considered math as more of a male domain than the other 2 groups. Attitudes toward math changed significantly only for the Attitude toward Success in Math Scale, which became more positive.

Leder, G. C. Mathematics Achievement and Fear of Success. Journal for Research in Mathematics Education, 1982, 13(2), 124-135.

The purpose of this study was to delineate and describe sex differences in math achievement and participation and to investigate the usefulness of the Fear of Success (FS) construct in explaining such differences. Students in grades 7, 10, and 11 were given the Tests of Reasoning in Mathematics (TRIM) to measure the students' math performance. The students also completed a questionnaire. Boys scored higher than the girls on the TRIM at every grade level except at Grade 11. At grades 10 and 11, more boys than girls intended to continue with 2 years of mathematics courses, whereas more girls than boys intended to opt out of math courses altogether. Boys with high FS intended to take no further math even though their current performance in math was relatively high. Girls high in FS intended to take 2 more mathematics courses.

Armstrong, J. M., and Price, R. A. Correlates and Predictors of Women's Mathematics Participation. Journal for Research in Mathematics Education, 1982, 13(2), 99-109.

Armstrong and Price designed a national survey to identify the relative importance of the many factors that may be affecting women's participation in mathematics. They concluded that there were 3 major factors which may affect women's and men's participation in math: (1) attidudes toward mathematics; (2) perceived usefulness of mathematics for educational and career goals; and (3) positive influences of parents, teachers, counselors, and peers. Teacher variables seemed to play a more important role in predicting female participation, while influences of parents and counselors appeared to be better predictors for males.

Pederson, K., Elmore, P., and Bleyer, D. Affective and Cognitive Mathematics Related Variables: A Longitudinal Study. Educational Resources Information Center, ED 265 011, Southern Illinois University, Carbondale, Illinois, September 1985, 43p.

The study investigated the relationships between cognitive and affective mathematics related variables and continuation in the mathematics study sequence. Subjects participated as 8th graders and again as 12th graders. Data were collected from various achievement tests, the Fennema-Sherman Mathematics Attitudes Scales, Unisex ACT Interest Inventory, and questionnaires. The results indicated that none of the attitude variables were related to continuing in math for high achieving females. Factors which influenced high achieving males were usefulness of math, effectance motivation, teacher's attitude, and parents' attitudes. Average females related confidence in learning math, positive perceptions of father toward daughter as learner of math, and father's perception of math as a male domain to continuing in math. The only factors related to average males continuing in math were confidence in learning and usefulness of math.

SOCIOLOGICAL FACTORS RELATED TO SEX DIFFERENCES

Student Attitudes

Fennema, E. H., and Sherman, J. A. Sex-Related Differences in Mathematics Achievement, Spatial Visualization and Affective Factors. American Educational Research Journal, 1977, 14(1), 51-71.

This study investigated the mathematics achievement of 1,233 9th - 12th grade students. Inspection of results indicated that males and females were similar in verbal ability and/or general ability. Males tended to rate mathematics more of a male domain and scored higher in mathematics confidence than did females. Their results led Fennema and Sherman to conclude that socio-cultural factors are important to the sex-related differences in mathematics achievement and spatial visualization.

Fennema, E. H., and Sherman, J. A. Sex-Related Differences in Mathematics Achievement and Related Factors: A Further Study. Journal for Research in Mathematics Education, 1978, 9(3), 189-203.

This was a follow-up study to the report Sherman and Fennema wrote in 1977 concerning the sex-related differences in math achievement in grades 9 - 12. This study was conducted in grades 6 - 8. Affective variables were tested by the Fennema-Sherman Mathematics Attitudes Scales. Significant sex-related differences were found for only 2 affective variables, confidence in learning math and math as a male domain. Males were more confident, and stereotyped math as a male domain at higher levels than did females. When the results from this study were looked at in conjunction with the results from the high school data, males were found to be more confident in their ability, stereotyped math at higher levels, perceived mothers and fathers as more positive, and perceived math as more useful. Girls showed less confidence in their ability before there was evidence that they were achieving at a lower level than boys. Girls tended to perceive math as less useful and to perceive less favorable attitudes on the part of teachers and parents.

Wolleat, P. L., Pedro, J. D., Becker, A. D., and Fennema, E. Sex Differences in High School Students' Causal Attributions of Performance in Mathematics. Journal for Research in Mathematics Education, 1980, 11(5), 356-366.

The Mathematics Attribution Scale and an achievement test were used for data collection in this paper. The results showed that the males' mean was higher than the females' on the Success-Ability subscale. The females' mean was higher on the Success-Effort subscale. Significant differences were also found on the Failure-Ability and Failure-Task subscales. In both cases, the mean of the females was higher than that of the males. At all levels of achievement, males scored higher on Success-Ability, while females scored higher on Failure-Ability. Females were more likely than males to use effort to explain their success in achievement.

Paulsen, K., and Johnson, M. Sex Role Attitudes and Mathematical Ability in 4th-, 8th-, and 11th- Grade Students from a High Socioeconomic Area. Developmental Psychology, 1983, 19(2), 210-214.

This study's intent was to further examine gender differences in subjects from a high-socioeconomic area. A sex role standards questionnaire was also completed by each student. Males and females did not differ in mathematics ability at any grade, and no significant differences in math ability were found across grade levels. Attitude differences were found however. Eleventh grade females were significantly more positive toward math than males. This trend approached significance in the 8th grade. Attitude toward math as sex appropriate was found to significantly affect math performance at the 4th and 8th grade levels. A final interesting result found that in the 8th grade, male examiners elicited significantly higher math raw scores than did female examiners for both sexes.

Franklin, M., and Wong, E. Reaching Math Potential. Educational Resources Information Center, ED 286 709, Research and Educational Planning Center, Reno, Nevada, August 1987, 178p.

Data for this study were obtained from questionnaires. Results obtained from a comparison of high-achieving and low-achieving girls indicated that high-achieving girls were more undecided about educational plans, chose more non-traditional careers and were much more unsure of ever reaching their career goal. They were also more influenced by their parents, especially fathers. Low-achieving girls were more likely to plan on working until they had children and were much less influenced by their parents. A comparison of high-achieving boys and high-achieving girls found their actual math and science achievement to be equal. Girls tended to rate their math ability lower than boys' math ability. Girls were not as positive in attitudes toward mathematics, had a lower degree of "liking for math", and rated their own popularity lower than the boys. Boys saw careers as financial necessities or societal expectations, while girls saw careers as providing challenges and personal fulfillments. High-achieving girls were still more unsure of ever reaching their career goals. When students were asked why women did not pursue careers in mathematics and science, both boys and girls listed social pressure and lack of parental encouragement as key reasons.

Teacher - Student Interactions

Leinhardt, G., Seewald, A. M., and Engel, M. Learning What's Taught: Sex Differences in Instruction. Journal of Educational Psychology, 1979, 71(4), 432-439.

This study examined the variation in frequency and percentage of academic and management contacts, amounts of instructional time, and the differences in initial and end-of-year performance between girls and boys in reading and mathematics. Teacher instructional behaviors were obtained from videotapes of reading and mathematics instruction. Results indicated that girls were given more academic contacts, had a higher percentage of contacts that were academic, and received more instructional time than boys did in reading classes. The opposite was true for math classes. In the math classes there was a higher overall rate of academic behavior on the part of the teacher. Boys received more management contacts in both classes. Those teachers who spent more time focused on academic material had students who performed better.

Becker, J. R. Differential Treatment of Females and Males in Mathematics Classes. Journal for Research in Mathematics Education, 1981, 12(1), 40-53.

The Brophy-Good Teacher-Child Dyadic Interaction System was used to compare teacher interactions with males and females in specific categories. Ten high school geometry teachers were observed a total of 10 times each. Results showed a consistent pattern for more teacher-initiated contacts with males. Teachers treated males and females differently in (a) afforded response opportunities, (b) open questioning, (c) cognitive level of questions,(d) sustenance and persistance, (e) praise and criticism, (f) encouragement, (g) individual help, and (h) conversation and joking. Teachers behaved in ways that involved young women less in classroom interactions and gave them less encouragement in math.

Fennema, E., and Reyes, L. H. Teacher/Peer Influences on Sex Differences in Mathematics Confidence. Final Report. Educational Resources Information Center, ED 219 237, National Institute of Education, Washington, D. C., October 1981, 227p.

This paper summarized data obtained from a 2 year study of 80 girls and boys in 7th and 8th grade. The Brophy-Good Dyadic Observation System was used to classify interactions. Significant sex differences in the mean frequency per day of Public Teacher-Student Interactions were found. Boys participated in many more interactions than did girls. Teachers initiated more interactions with boys. Teachers asked boys more questions for discipline purposes. Teachers asked boys more higher level mathematics questions, as well as more lower level and more non-mathematical questions. Boys appeared to be more active initiators of interactions. Boys volunteered to answer more questions and called out more responses without waiting for teacher recognition. Sex differences were not found in a number of private interactions. The researchers also noticed that blatant sexism did not exist, except very occasionally, in the classrooms.

McDermott, M. The Impact of Classroom Interaction Patterns on Students Achievement - Related Beliefs and Behaviors. Educational Resources Information Center, ED 237 206, Society for Research in Child Development, Detroit, Michigan, April 1983, 19p.

Seventh, eighth, and ninth grade math classes were observed for 10 days each. Questionnaires were also completed by the students and the teachers being observed. Teachers were asked to rate their expectations for each student's math performance. Students were then divided into high and low expectancy groups. Analysis of the observations found that males received more criticism, a higher average number of sustaining questions and more dyads with brief feedback. Females were significantly higher than males only on the percent of total work praise received. Dyads with brief feedback were positively related to teacher expectancy for all students. Teacher expectation for low females was positively correlated with work praise, but for high females, teacher expectation was positively correlated with percent of work criticism.

Gore, D. A., and Roumagoux, D. V. Wait-Time as a Variable in Sex-Related Differences During Fourth-Grade Mathematics Instruction. Journal of Educational Research, 1983, 76(5), 273-275.

The paper focused on teacher expectations as an explanation for different achievement in mathematics for boys and girls. Differences in teacher wait-times for girls and boys during mathematics instruction were assessed. Five teachers with varying degrees of experience were observed during 10 mathematics teaching sessions of 45 minutes each. Significant differences were found in favor of the boys for the sample as a whole. The scope of the study was rather limited. All five teachers were from one school in Northwest Arkansas.

Peterson, P. L., and Fennema, E. Effective Teaching, Student Engagement in Classroom Activities, and Sex-Related Differences in Learning Mathematics. American Educational Research Journal, 1985, 22(3), 309-335.

The authors observed in 36 fourth grade classrooms. Students' math achievement was pre-tested in January and then tested again in May. No significant differences were found in math achievement on either test. Low level math achievement of boys was negatively related to the amount of time they spent on one to one interaction with the teacher, amount of time spent being helped by the teacher, and amount of time spent in off-task activities. One of the most important variables for girls was the extent to which they engaged in math activities that were cooperative. Math activities in which no helping occurred and activities that were neither cooperative nor competitive were positively related to high level achievement for both girls and boys. Girls achieved less on high level mathematics in classes in which a greater percentage of time was spent in teacher-sanctioned social activity. Cooperative activities were positively related to girls' achievement, while it was negatively related to boys' achievement. Girls did better on high level achievement when taught in small groups. Boys did better when the greater amount of time was spent on individual interaction with the teacher.

Parent Attitudes

Wilhelm, S and Brooks, D. M. The Relationship Between Pupil Attitudes toward Mathematics and Parental Attitudes toward Mathematics. Educational Research Quarterly, 1980, 5(2), 8-16.

The main purpose for this study was to investigate the relationship between parental attitudes toward math and student attitudes. Over two hundred 7th, 8th, and 9th graders were given the Mathematics Attitude Inventory and 2 copies of an edited version for their parents to fill out. Father's enjoyment of math was inversely related to a son's enjoyment while it appeared to be more similar to a daughter's enjoyment. Fathers did not share the same opinion about the value of math as did low ability sons or medium ability daughters. Mothers appeared to have a considerable amount of influence on anxiety toward math felt by daughters. The same relationship appeared between fathers and sons. Parental influence tended to dissipate as the ability level of the child increased.

Jayaratne, T. E. Sex Differences in Children's Math Achievement: Parental Attitudes. Educational Resources Information Center, ED 235 927, Society for Research in Child Development, Detroit, Michigan, April 1983, 14p.

Parents' perceptions of their own past and present math achievement and their perceptions of the math abilities and attitudes of their daughters and sons were investigated. Data were obtained from parents by questionnaires on 2 separate occasions 1 year apart. Data on each student from achievement test scores and from class grades were obtained. Fathers indicated a more positive attitude toward both past and present mathematics. Mothers were more likely to recall having done well in high school overall and to have felt it was important to do well. The majority of mothers and fathers believed that males do better in math and have more use for math in their adult lives. Parents of daughters were more likely to say males and females had equal math ability. Parents of sons indicated a more positive attitude and evaluation of their child's math achievement than did parents of daughters. Parents' general stereotypes about mathematics did not, however, relate to the sex differentiation of mathematics achievement for their children.

Pederson, L., Elmore, P., and Bleyer, D. Parent Attitudes and Student Career Interests in Junior High School. Journal for Research in Mathematics Education, 1986(a), 17(1), 49-59.

Parent attitudes and student career interests in relation to their contribution to a theoretical model of math achievement in junior high was the major purpose of this study. The Fennema-Sherman Mathematics Attitudes Scales were used to measure student and parent attitudes. Student career interests were measured by the Unisex ACT Interest Inventory. The contribution of parent attitudes to the variance of math achievement was significant over and above the contribution of the other variables. Student career interests were significant predictors of math achievement over and above spatial visualization ability, student attitudes, sex, and parent attitudes.

Pederson, L., Elmore, P., and Bleyer, D. Parent Careers and Attitude toward Mathematics as a Male Domain. Educational Resources Information Center, ED 274 550, American Educational Research Association, San Francisco, California, April 1986(b), 31p.

This study compared the relationship between parents' careers and students' attitudes toward math as a male domain. Data were gathered through the Mathematics as a Male Domain Subscale of the Fennema-Sherman Mathematics Attitude Scales and a questionnaire sent to the parents. Fathers who were employed in predominantly male occupations perceived math to be more of a male domain and influenced their sons to perceive the same. Daughters attitudes toward math as a male domain was patterned after both parents. Students exhibited less stereotyping if father had a career in management, business operations, or services. Mothers who were housewives did not affect daughter's or son's attitudes.

Dunton, K. J., McDevitt, T. M., and Hess, R. D. Origins of Mothers' Attributions About Their Daughters' and Sons' Performance in Mathematics in Sixth Grade. Merrill-Palmer Quarterly, 1988, 34(1), 47-70.

When children were 5 or 6 years old, a variety of tests and interviews of the mothers were administered by the authors. A follow-up study was then conducted when the children were in the 6th grade. Boys did slightly better on the 6th grade achievement test. Mothers of girls attributed their daughters' failures to lack of ability, and their successes to having put forth effort. Mothers of sons used the opposite pattern. Mothers who perceived that their children were doing relatively well in math attributed their children's success to having ability and their failure to a lack of effort. The opposite was true when mothers perceived that their children were doing relatively poorly.

SUMMARY

Sex differences in mathematics achievement of students at all grade levels have been the focus of much debate and research in the last decade. Researchers have found that sex differences do exist. The debate has focused on what these differences were, when they occurred, and what caused the differences. The sex differences in achievement were found to favor males in all but a few selected studies. A report of the National Assessment of Educational Progress (NAEP) showed no clear pattern of differences in achievement for students at ages 9 or 13. Females tended to be higher on knowledge and skills exercises, while males were slightly higher on applications and understanding exercises. These differences were not significant, however. At age 17, the differences were significant in favor of males at every cognitive level (Fennema and Carpenter: 1981). Another study conducted by the Youth Cohort of the National Longitudinal Study of Labor Force Behavior (NLS) found similar results. This study indicated that females who had completed grade 8 scored slightly higher than males on tests of mathematics knowledge, but males excelled when compared with females who had completed high school. Arithmetic reasoning tests showed male advantages much earlier and females did not hold an advantage at any level (Moore and Smith: 1987). Results of the Women in Mathematics Project agreed with the NAEP and NLS results (Armstrong: 1981). All three of these studies found that females tended to start out at a similar level of

mathematics achievement, but lost ground to the males at some time during high school.

Other more limited studies were conducted which did not show this trend. A study of the use of spatial visualizaton to solve mathematical problems gave a slight advantage to males over females; however, the intrasex differences were larger than the intersex differences (Fennema and Tartre: 1985). One study which has attracted a lot of attention was conducted by the Study of Mathematically Precocious Youth. The data collected showed large sex differences in favor of the males in the 7th and 8th grade (Benbow and Stanley: 1980). This difference appeared much earlier than the differences in the three national surveys. Two possible explanations for this contradiction existed in the literature. One explanation of the contradiction was that Benbow and Stanley tested only those who were considered academically talented instead of a national sample. Another possible explanation was proposed by Senk and Usiskin in their study of geometry students. They found that when female and male students were tested on a high-level cognitive topic which was encountered almost exclusively in school, there was not a pattern of sex differences (Senk and Usiskin: 1983). Another study agreed that instruction in school did not effect one sex more than the other (Hanna: 1986). Benbow and Stanley used SAT tests whose items are relatively unfamiliar and therefore may be greatly influenced by experiences outside of school. Senk and Usiskin suggested that highly able males were more likely to be involved in mathematically related topics

outside of school which would enhance their scores on the SAT (Senk and Usiskin: 1983).

One final study which deserved mentioned was the study conducted by Brandon and others on children in Hawaii. This investigation found that Hawaii public school girls had higher achievement levels than the boys. These results were less significant among Caucasion students than they were among the Japanese-American, Filipino-American, and Hawaiian students. Sociocultural influences were discussed as a possible reason for these unusual circumstances (Brandon et al.: 1987).

A potential rationale for the gain males acquired in math during the high school years was sex differences in course enrollment. The Women in Mathematics survey discovered that few sex differences in mathematics participation occurred for lower level courses such as Algebra I and geometry. After these courses however, significantly more females reported taking business or accounting mathematics, while more males reported taking Algebra II and probability and statistics. The NAEP found significant sex differences in favor of males, for the courses of trigonometry and precalculus/calculus (Armstrong: 1981). These findings were confirmed by other surveys as well (deWolf: 1981, Pallas and Alexander: 1983). Even though more males tended to enroll in higher level math courses, the females that did enroll tended to receive higher grades than the males. It was also disclosed that when coursework was controlled, the differences between males and females in achievement were considerably less (deWolf: 1981, Pallas and Alexander: 1983).

One recent study was found to contradict earlier findings. The 1985 senior class in Rhode Island was surveyed. Results showed that more females had enrolled in the pre-college sequence and received higher grades than males (Rallis and Ahern: 1986). The female advantage was not as large, however, as some of the male advantages reported in earlier research.

Once a variance in course enrollments was established, investigators started to study the factors which may influence students to enroll in higher level mathematics courses. Julia Sherman discovered that female groups that continued in mathematics were not more select than the male groups. Spatial visualization was the most important factor for females continuing in mathematics, but it was the least important for males (Sherman: 1981). Another study suggested that confidence in learning mathematics was a very important factor for male continuation in mathematics (Sherman: 1983). A third investigation of seniors who had taken higher level courses found that both sexes listed usefulness of mathematics, as well as confidence in, and enjoyment of mathematics as important reasons for continuation. The best predictors, from outside sources, for female participation was father's educational expectations, teacher encouragement, and teacher's lack of stereotyping. For males, the best predictors were the influences of parents and counselors rather than the teacher (Armstrong and Price: 1982). A related study stated that males with a high Fear of Success intended to not take more mathematics while females with a high Fear of Success did intend

to take more mathematics (Leder: 1982). Benbow and Stanley suggested that lower female participation in mathematics may be caused by a greater female liking for the verbal areas, rather than an aversion to math areas (Benbow and Stanley: 1982).

Not only have inequalities been revealed between male and female enrollment in general, but differences were also found between high- and low- achieving males and females. The first investigation found that as the students got older, females and males that had a high-level of achievement were equal in their intentions to continue in math. For those in the low-level group, however, more males than females intended to continue (Sherman and Fennema: 1977). A similar inspection revealed that high-achieving males were influenced by the usefulness of math, effectance motivation, teacher's attitude, and parents' attitudes. Average-achieving females were influenced by confidence in learning math, positive perceptions of father toward daughter as a learner of math, and father's perception of math as a male domain. Confidence in learning math and usefulness of math were the only factors which were related to average males. None of the attitude variables were related to the high achieving females (Pederson et al.: 1985).

Attitude variables were reported to be very influential predictors to continuing to take mathematics courses, as can be seen above. Students' attitudes were also shown to have an effect on mathematics performance. An examination of students in a high-socioeconomic area found that no sex differences in mathematics ability were found at any grade level. An analysis

of the results determined that both sexes had a positive attitude toward math, with 11th grade females' attitudes toward math significantly more positive than males' attitudes. There was also a direct corrolation between an attitude toward math as appropriate for one's sex and high math scores (Paulsen and Johnson: 1983). Differing attitudes between high-achieving and low-achieving females were discussed in another study. Results indicated that high-achieving females were more undecided about educational plans, chose more non-traditional careers, were more unsure of ever reaching their career goals, and were more influenced by parents than low-achieving females. Comparisons of males and females showed females with not as positive an attitude toward mathematics, a lower degree of "liking for math", and a lower perception of ability and popularity than the males (Franklin and Wong: 1987). Two studies conducted by Fennema and Sherman agreed that males tended to rate mathematics as more of a male domain and were higher in mathematics confidence than females (Fennema and Sherman: 1977, 1978). Significant differences between males and females were discovered in the attributions connected with success and failure. Males tended to attribute success to ability, while females attributed it to effort. Females were more likely to attribute failure to a lack of ability or to the difficulty of the task than males (Wolleat et al.: 1980).

Influences of teachers on the continued enrollment of females in mathematics was proven in studies reported earlier. For this reason, the next logical step for investigation was

teacher-student interactions. One such investigation found that there were far more teacher-initiated interactions with males than with females. Teachers also asked boys more questions for discipline purposes and asked boys more higher-level mathematics questions (Fennema and Reyes: 1981). These results were corroborated by two other studies (Leinhardt et al: 1979, Becker: 1981). Another study focused on the differences in teacher wait-times. Teachers were discovered to have given significantly more wait-time to boys than to girls (Gore and Roumagoux: 1983). Marilyn McDermott related teacher interactions to teacher expectations. Dyads with brief feedback were positively related to high teacher expectancy and males received more of these than females. Females received a higher percentage of work praise than males, which was positively related to teacher expectation for low expectancy females. For high expectancy females, on the other hand, teacher expectation was positively correlated with the percentage of work criticism (McDermott: 1983). The classroom processes and activities used by the teacher and students were also found to be important to math achievement. The amount of time spent on cooperative math activities was very important to the math achievement of females, but negatively related to male achievement. Both boys and girls benefited from activities in which no helping occurred and which were neither cooperative nor competitive. Females did better in classes in which less time was spent in social activity (Peterson and Fennema: 1985).

Parental attitudes were related to their children's

attitudes in several ways. One study found that mothers appeared to have a great influence on anxiety toward mathematics felt by the daughter. The same was true for the father and son relationship. Fathers and daughters tended to share a similar enjoyment of math. The relationships varied according to the ability level of the student (Wilhelm and Brooks: 1980). Another investigation discovered that the majority of parents believed that males do better and have more use for mathematics as adults. These general stereotypes did not relate to the sex difference of students in math achievement (Jayaratne: 1983). The contribution of parent attitudes to the variance of mathematics achievement was considered significant over and above the contribution of any other variable (Pederson et al.: 1986(a)). Mothers' attributions for their children's performance was investigated in the next study. The results showed that mothers of girls attributed their daughters' failures to a lack of ability and attributed their daughters' successes to effort. The opposite was true for mothers of boys (Dunton et al.: 1988). Not only parent attitudes were studied, but also parent careers and their relationship to the student's attitude toward math as a male domain. Both fathers and sons perceived math as more of a male domain when the fathers were employed in predominantly male occupations. Daughters' attitudes were patterned after both parents' careers. Mothers who were housewives did not seem to affect daughters' or sons' attitudes (Pederson et al.: 1986(b)).

CONCLUSIONS

Sex differences did exist in all of the nationally conducted surveys. At the junior high level, females tended to achieve higher on tests of basic knowledge and computation, while males tended to score higher on application exercises. By the end of high school however, males had overtaken and surpassed females at every cognitive level. The information which did not agree with the surveys was based on much smaller samples. Spatial visualization skills were concluded to be important to math achievement, but did not cause significant differences in the sexes.

Differential course enrollment was concluded to be a possible explanation for the sex differences found in the high school. Benbow and Stanley argued against this theory because the differences they observed were found before males and females differed in the math courses taken (Benbow and Stanley: 1980). "Even if we accept Benbow and Stanley's findings as relevant to the differential coursework hypothesis, we must wonder whether they are applicable only to highly able youth" (Pallis and Alexander: 1983). Males took more higher-level courses, such as Algebra II, probability and statistics, trigonometry, and precalculus/calculus, than did females. A 1985 survey of Rhode Island seniors showed that this trend may be changing. At the present time, females are still behind males in math achievement and they will need to overcompensate to catch up.

Reasons for enrolling in upper level math courses differed by sex. Spatial visualization, high Fear of Success, confidence in learning math, usefulness of math, and enjoyment of math were all internal factors which affected females. Females were also influenced by outside factors such as father's perception of daughter as a learner of math, father's perception of math as a male domain, teacher's encouragement, and teacher's lack of stereotyping. Males seemed to need less motivation to continue in mathematics. The main internal factors were confidence in learning math, usefulness of math, and enjoyment of math. Parents and counselors were the only outside forces which influenced males to continue in math. Sherman and Fennema noted that "in the eleventh grade, there was no difference between boys and girls in the top half of their class in intent to continue in mathematics, but more boys than girls in the lower half of their class plannned to continue" (Sherman and Fennema: 1977).

Sex differences in student attitudes were also found. It was concluded that males had a more positive attitude toward math, had higher confidence in their ability, had stereotyped math as more of a male domain, and rated their own popularity higher than females did. Females, especially high-achieving females, were more unsure of reaching their career goals than males. These differences in attitude were clearly seen when students listed the reasons for their success or failure in math. Wolleat concluded that females were more likely than males to blame failure on a lack of ability or the difficulty of

the task. Males' higher confidence showed when success was attributed to having ability, while females, without high confidence, attributed success to much effort.

It can be concluded that teachers were contributing to the stereotypes associated with mathematics. Teachers in mathematics classrooms initiated more interactions with males, waited longer for males to answer questions, interacted with males more for discipline purposes, and asked males more higher-level questions than females. The only type of interaction found to be higher for females was work praise. Females soon learned that they were to be passive in the classroom. Another fact important to teachers was concluded by Peterson and Fennema. The classroom processes which were effective for males were not effective for females. Cooperative activities were determined to be very important for the math achievement of females, but were not related to the achievement of males. Males and females both benefited from activities which were neither competitive nor cooperative (Peterson and Fennema: 1985).

Sex differences were found in parents' attitudes whether they had a son or daughter. The degree to which these attitudes affected the children varied. A strong influence was shown between mothers and daughters, and fathers and sons on anxiety felt toward mathematics. The only attitude shared by fathers and daughters was enjoyment of math. A majority of parents believed that males did better and had more use for mathematics. Mothers of males and mothers of females assigned different

attributes for success and failure in math. A connection was also made between fathers who were employed in predominately male occupations and the perception of math as more of a male domain by the sons. Daughters' attitudes were affected by both parents' careers.

Educators must be aware of the factors which can cause females not to achieve up to their potentials in mathematics. As role models and guides, their influence on females and males to continue in mathematics could either help eliminate these differences or help reinforce them.

RECOMMENDATIONS

It is recommended that:

1. Teachers at all levels eliminate any sex bias in classroom interactions or classroom activities.
2. Educators and parents encourage all students to continue in mathematics to keep their career options open.
3. Research be conducted on sex differences of math-related activities which occur outside of the school setting and their relationship to math achievement.
4. Educators and parents help students develop confidence in their ability to do mathematics successfully.
5. Educators demonstrate to students the usefulness of math in their lives.
6. Research be conducted on the effects on girls' and boys' low-level and high-level mathematics learning when the frequency of certain mathematics activities is manipulated (Peterson and Fennema: 1985).
7. Research be directed toward the feasibility and advisability of teaching spatial visualization in the schools (Sherman: 1981).
8. Teachers at all levels actively help their students to overcome the sex stereotyping of mathematics.
9. Teachers and parents cooperate to increase the supportive conditions and encourage perseverance at home.

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